NASA

Technical Memorandum **80554**

(NASA-TM-80554) HEAO-1 SPECTRA OF X-RAY EMITTING SEYFERT 1 GALAXIES (NASA) 29 p HC A03/MF A01 CSCL 03B

N79-31117

Unclas
G3/90 36077

HEAO-1 Spectra of X-Ray Emitting Seyfert I Galaxies

R. F. Mushotzky, F. E. Marshall, E. A. Boldt, S. S. Holt, and P. J. Serlemitsos

AUGUST 1979

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

HEAO-1 SPECTRA OF X-RAY EMITTING SEYFERT I GALAXIES

R.F. Mushotzky*, F.E. Marshall*, E.A. Boldt, S.S. Holt,
and P.J. Serlemitsos

Laboratory for High Energy Astrophysics
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

ABSTRACT

The A-2 experiment on HEAO-1 has determined spectral parameters for 7 Seyfert I galaxies: NGC3783, NGC4151, NGC5548, NGC6814, MK509, MCG8-11-11 and ES0141-G55. The X-ray spectra above 5 keV can be well fit by power laws of energy index α, $.3 < \alpha < 1.0$ and with the exception of MK509 by a high temperature $kT > 15$ keV, thermal bremsstrahlung spectrum. The column densities, with the exception of NGC4151, are less than 5×10^{22} at/cm^2 with only the low luminosity objects having measurable columns. ES0141-G55 shows a strong soft X-ray excess in March 1978 similar to that seen in the BL Lac object MK421. MCG8-11-11, NGC3783, and possibly NGC6814 exhibited variability on a 6 month time scale. Various correlations between optical and X-ray properties are discussed. Using the typical Seyfert I spectrum we compute their contribution to the diffuse X-ray background above 5 keV.

Subject headings: galaxies: Seyfert - X-Rays: spectra

* NAS/NRC Research Associate

I. INTRODUCTION

The existence of Seyfert I's as a class of X-ray emitting galaxies has recently been established (Elvis et al. 1978; Tananbaum et al. 1978; Marshall et al. 1979a). At present there are ∿ 25 X-ray emitting Seyfert I's detected out of the ∿100 such objects known optically (Weedman 1977,1978). Despite the large number of these objects their low X-ray flux, typically $< 5 \times 10^{-11}$ ergs/cm^2 sec in the 2-10 keV band, has restricted our knowledge of their X-ray spectra. To date only three have had their X-ray spectral parameters determined, NGC4151 (Ives, Sanford and Penston 1978; Mushotzky, Holt and Serlemitsos 1978), NGC5548 (Stark, Burnell, and Culhane 1978; Rothschild et al. 1978), and MK279 (Stark et al. 1978).

In this paper we present the 2-60 keV X-ray spectra and time variability information on 7 Seyfert I galaxies: NGC3783, NGC4151, NGC5548, NGC6814, MK509, MCG8-11-11 and ESO 141-G55 obtained with the A-2[+] experiment on HEAO-1. More detailed analysis will be presented in a later paper on NGC4151 including data from a June 1978 series of pointed observations. With this larger sample we have attempted to correlate the X-ray spectral properties of these objects with their optical and radio properties.

[+]The HEAO A-2 experiment is a collaborative effort led by E. Boldt of GSFC and G. Garmire of CIT, with collaborators at GSFC, CIT, JPL and UCB.

II. OBSERVATIONS

The HEAO 1 A-2 experiment has been described in detail by Rothschild et al. 1979. It consists of 6 multi-wire, multi-layer gas proportional counters sensitive over the .15-60 keV band. For the observations reported in this paper we have used the argon and xenon counters with an effective area of ~ 800 cm^2 each and with $3^o \times 3^o$ and $3^o \times 1.5^o$ field of views. The detectors have an energy resolution of $\sim$ 18% (FWHM) at 5.9 keV. The argon detector has a 3 mil beryllium window and is sensitive in the 2-20 keV band. The xenon counter have a propane anticoincidence layer contained within two 1 mil mylar windows, in front of the collecting volume and is sensitive in the 2.5-60 keV band. For the observations reported in this paper integral count rates were obtained every 5.12 seconds and pulse heights were accumulated on a 10.24 sec basis.

We have obtained data from both the scanning and pointed modes of observation. In the scanning mode an object is typically in the field of view for 6 days and a total exposure time of $\sim$ 2000 seconds. Background is obtained over the same time interval as the source observation from source free regions near the source. In the pointed mode the satellite is pointed at the source for 3-12 hours, resulting in 5000-20,000 seconds of observing time. Background is obtained from scanning or pointed observations of source free regions close in time. A log of the observations is presented in Table 1.

Our scanning mode observations allow error boxes for all these sources to be determined following the method of Marshall et al. 1979a. In all cases (Fig. 1) our error boxes agree with the suggested identifications of the X-ray source with the optical Seyfert galaxy. Forty arc sec modulation collimator error boxes from the A-3 experiment on HEAO-1 for MCG8-11-11, NGC4151 and ESO141-G55 have been reported by Griffiths _et al._ 1978.

III. RESULTS

A. Spectra

The spectral results for the 7 Seyfert I galaxies are listed in Table 2 and shown in Fig. 2. All quoted errors are 2 parameter joint 90% confidence errors determined from the prescription of Lampton, Margon and Bowyer (1976) and refer to the rectangular box which fully encloses the 90% confidence parameter. We detect all these objects out to 20 keV and those where we have the most counts out to 40 keV. The data are well fit for all but MK509 by either a power law or a high temperature thermal bremsstrahlung. For MK509 the power law is a significantly better fit than the thermal model. In none of these sources with the exception of NGC4151 was a Fe feature either in emission or absorption required but our statistics allow lines of up to 250 eV equivalent width to be present, consistent with previous results for Cen A (Mushotzky et al. 1978a) and NGC4151 (Mushotzky et al. 1978b).

The column densities for these other sources are significantly lower than that for NGC4151 thus making that object somewhat anomalous. Only the low luminosity objects, $L_x < 5 \times 10^{43}$ ergs/sec in the 2-10 keV band, have measurable column densities. The high luminosity objects (MK509, ESO141-G55, NGC5548 and MCG8-11-11) all have only upper limits on their columns. This is unlikely to be a selection effect since all of the objects in this sample, with the exception of NGC4151, have approximately the same 2-10 keV fluxes (Table 3). Our spectral parameters for NGC5548 agree with those determined previously by Stark et al.

B. Intensity and Spectral Variability

In general the fluxes derived with the HEAO-1 A-2 experiment for these sources differ from those determined by other experiments. However because these sources were relatively weak for the Uhuru and Ariel-V experiments systematic errors make the direct comparison of 4U and 2A fluxes with HEAO-1 fluxes subject to error.

Comparison of fluxes determined on the two different scanning observations by HEAO-1 6 months apart are free of such systematic errors. In Figure 3 and Table 4 we show the counting rate in the 4-17 keV band (Marshall et al. 1979a) for 7 Seyfert I galaxies. We note that NGC4151, NGC3783, and MCG8-11-11 are clearly variable by more than 50% while ESO141-G55, MK509 and NGC5548 showed no detectable variation and NGC6814 was possibly variable. Previous authors have noted variability on a 30 day time scale for MCG8-11-11 (Ward et al. 1978), on several timescales for NGC4151 (Tananbaum et al. 1978; Mushotzky et al. 1978b) and on a yearly timescale for NGC5548 (Rothschild et al. 1978).

On timescales shorter than 6 months we have evidence for variability in NGC4151, NGC3783 and NGC6814. For all the other sources upper limits of a factor of 2 on timescales from 6 hrs. to 1 day and 50% from 1-6 days can be set. For NGC3783 comparison of the flux derived from scanning on days 183-188 of 1978 with the pointed observation on day 190 indicates at least a factor 4 increase in flux occurred. Scanning data from the fall 1977 observation of NGC6814 show gradual $\sim$ 30% modulation over a 7 day timescale. The variability of NGC4151 will be discussed in a later paper.

It is interesting to note that, in the HEAO-1 data, it is only the less luminous Seyferts that vary strongly at $E > 4$ keV. This might suggest a relationship between variability time scale (size?) and luminosity.

There is no evidence for spectral variability at $E > 4$ keV in this sample of objects. Table 1 shows that within errors the power law indices have not varied over a time scale of 6 months. In addition, with the exception of NGC4151, there is no evidence for changes in the X-ray column density N_x. However, comparison of the scanning and pointed observations of ESO141-G55 (Fig. 4) shows this source to have varied by a factor of 2.1 $\pm$ .1 in 2-4 keV integral intensity while its intensity and spectrum at E > 4 keV remained roughly constant. The spectrum seen in spring 1978 is similar to BL Lac objects (Mushotzky et al. 1978c).

IV. DISCUSSION OF SPECTRA

A. Continuum

Our data indicate that both power laws and thermal models, in general, provide acceptable fits to the data. However the temperatures determined from the thermal models are lower limits except for NGC5548 and MK509. These lower limits are at the upper range of our energy band. The χ^2 per degree of freedom differs significantly only for MK509 and NGC3783 for thermal vs. power law fits. This slight evidence combined with similar evidence for NGC4151 (Mushotzky, Holt, Serlemitsos 1978; and Baity et al 1976) seem to indicate a preference for a power law model fits in Seyfert I galaxies.

For a power law fit the energy indices seem to be distributed around a mean index of $\alpha \simeq .65$ with a 1σ dispersion of 0.1. For none of the spectra is a high energy cutoff indicated and therefore for all of these objects their 2-60 keV fluxes are considerably higher than the 2-6 or 2-10 keV flux (Table 3). When the 2-60 keV fluxes are used it is clear that the X-ray flux dominates that in any other observed spectral band.

B. Low Energy Absorption

None of the objects whose spectra are determined in this paper require large column densities. This, at first, may seem to be in conflict with models (Mushotzky et al. 1978b) in which the X-ray emission lies within the optical emission line volume. Recent work by Shields and Mushotzky (1978) shows, however, that the column densities measured here are not unexpected. For a large sample of observations one would expect correlations amongst optical line parameters and X-ray column density. Unfortunately our measurements are not well determined enough to perform such correlations in detail.

The fact that the column can range from $< 1 \times 10^{22}$ to $> 1 \times 10^{23}$ in these sources makes it quite difficult to compute their contribution to the 2-6 keV background (see Schwartz 1979 for a discussion of this topic; see the next section for a detailed discussion of the 4-50 keV contribution). Similarily the detection of a lower energy excess in ES0141-G55 indicates that in some sources the existence of a low energy component can mask the effects of low energy absorption. The 7.1 keV absorption edge of Fe is not subject to such an effect and future observations with higher sensitivity will be able to detect this feature.

V. CONTRIBUTION TO X-RAY BACKGROUND

We will use the X-ray spectra of the Seyfert galaxies measured in this paper to calculate the contribution of Seyferts to the unresolved X-ray background as a function of energy. Previous work has been done only for the integrated 2 to 10 keV band. Elvis et al. (1978) computed the local volume emissivity of Seyferts to be 6% $\pm$ 3% of that needed to produce the X-ray background. Tananbaum et al. 1978 found the value to be between 9% and 19%.

We will compare intensities rather than volume emissivities since the intensity of the X-ray background is the observable and the relationship between volume emissivity and intensity depends on the shape of the source spectrum.

The intensity, I, produced by a volume emissivity B is (Avni 1978)

$$I(E) = \frac{C}{4\pi H_o} \int_o^{Z_F} \frac{B(E\,(1+Z),\,Z)\,dZ}{(1+Z)^2\,\sqrt{1+2q_oZ}} \tag{1}$$

in which z is redshift, and q_o is the deceleration parameter. H_o is taken to be 50 km $s^{-1}Mpc^{-1}$. We assume that 25%, 50%, and 25% of the 2-10 keV luminosity is due to Seyferts with spectral indices of 0.51, 0.65, and 0.79 respectively. We will restrict the comparison to E > 4 keV since Seyferts exhibit a wide variety of spectra at lower energies.

The local volume emissivity, B_o, requires knowing the local luminosity function of Seyfert galaxies. Using the brightest known Seyferts, Tananbaum et al. calculated

$$n(L) = 4.1 \times 10^{-7}\, L_{44}^{-2.3} \quad Mpc^{-3} \tag{2}$$

for L_{44} from .032 to 10, in which L_{44} has units of 10^{44} erg s^{-1}.

The luminosity function calculated by Elvis et al. produces only 44% of the volume emissivity of that of Tananbaum et al. This difference presumably reflects the difficulty in correcting for incompleteness in optical and X-ray surveys, misidentifications, source variability, etc. We have made a different calculation which minimizes these difficulties. The new calculation uses the results of fluctuation analysis to normalize the luminosity function. This technique increases the number of X-ray sources included and can set an upper limit on the normalization without regard to optical identifications. For uniform distribution of sources in Euclidean space, the number of sources with intensity greater than S is

$$N(>S) = K \; S^{-3/2}. \qquad (3)$$

Analysis of source counts (Warwick and Pye 1978) and fluctuations (cf. Schwartz 1979) indicate $K \sim 15$ sr^{-1} for S measured in UFU. Only a fraction of these sources are Seyfert galaxies:

$$K_{SEY} = fK \quad 0 < f < 1 \qquad (4)$$

The value of f can be estimated from a sample of sources complete down to a given intensity. Such a sample based on the 2A catalog is given by Warwick and Pye (1979). Sixteen per cent of the 67 sources were identified with Seyfert 1 galaxies while 25% had no identification. Limits on f of 0.16 and 0.41 can be put assuming that none and all of the unidentified sources are Seyferts. The luminosity function from Tananbaum et al. is consistent with an f of 0.32. We will adopt this value, mindful that it is possible the correct value could be only half as much. It seems unlikely that correct value could be much larger since this would require more than half the unidentified sources to be Seyferts.

Figure 5 shows the contribution of Seyferts (C_s) to the unresolved X-ray background (Marshall et al. 1979b) produced by the luminosity function given in eq. 2, assuming no Seyfert evolution, $q_o = 0$, and $z_F = 3$. The plot indicates that, given assumptions of the model, Seyferts are a small fraction of the X-ray background in the 4-50 keV range. The plot also shows that in the 4 to 8 keV band, these Seyferts have a softer spectrum than that needed to produce the XRB, and (assuming the power law extrapolation is valid) a harder spectrum for $E \gtrsim 20$ keV.

For $q_o = 1$, C_s is 0.68 times as large as shown, while increasing z_F from 3 to 4 multiplies C_s by only 1.03. As pointed out by Avni (1978), C_S can be significantly increased if the number density of Seyferts per comoving volume element increases with z. For $\rho(z) = \rho_o \, (1+z)^3$, C_S is multiplied by 7.6, which would make $C_S \gtrsim 1$. However, since $\sim 0.5\%$ of local galaxies are Seyferts (Weedman 1977), this requires ~ 1/3 of all galaxies to be Seyferts at z = 3. There is no evidence of such a strong evolution of Seyfert galaxies. In addition, the spectrum is probably inconsistent with that of the X-ray background.

VI. CORRELATIONS

Various models of X-ray emission in these objects have suggested that the X-ray properties of these objects should be correlated with their optical, IR or radio properties. We find that the X-ray power law index does not correlate with either X-ray luminosity or the full width zero intensity (FWZI) of Hβ (Fig. 6). In a model in which the X-ray flux originates in shocked clouds with a temperature related to the Doppler velocity of the clouds such correlations might be expected.

In a self-Compton model (Mushotzky 1977) one might expect a correlation between X-ray spectral index and optical/IR spectral indices. We have fit power laws to the "red", log γ < 14.8 Hz, continua of all the X-ray Seyferts in the paper of deBruyn and Sargent (1978) in the present sample. A weak correlation (Fig. 7) between α_x and α_{op} exists with MK509 having a somewhat flatter α_{op} than expected from the other 4 objects. The best fit relations between α_x, α_{op} and α_{IR} (Rieke 1979) do not give a consistent fit. Thus it is unclear what, if any, relation exists between the IR, optical and X-ray fluxes.

At the present time we feel that the data due not allow strong statements to be made about any model. Further observations are clearly necessary.

VII. SUMMARY

The spectra of Seyfert I galaxies can be well represented by flat power laws or high temperature thermal bremsstrahlung models with relatively low column densities. No high energy cut offs E < 20 keV are detected. Some but not all of these objects are variable in intensity on a 6 month timescale. Further HEAO-1 observations will increase to ~ 15 the number of Seyfert I's with known spectra. Similarly HEAO-2 observations of these objects will accurately determine their column densities. We thus expect a wealth of material in the next year which should enable wider correlative studies.

REFERENCES

Avni, Y. 1979, Astron & Astroph 63, L13.

Baity, W.A., Jones, T.W., Wheaton, W.A. and Peterson, L.E. 1975, Ap. J. (Letters) 199, L5.

deBruyn, A.F. and Sargent, W.L. 1978, Ap. J. 83, 1257.

Elvis, M., Maccacaro, T., Wilson, A.S., Ward, M.J., Penston, M.V., Fosbury, R.A.E. and Perola, G.C. 1978, M.N.R.A.S. 183, 129.

Griffiths, R.E., Bradt, H., Briel, U., Doxsey, R.E., Johnston, M., Schwartz, D.A. and Schwartz, J. 1978, B.A.A.S. 10, 503.

Ives, J.C., Sanford, P.W., Penston, M.V. 1976, Ap. J. (Letters) 207, L159

Lampton, M., Margon, B., and Bowyer, S. 1976, Ap. J. 208, 177.

Marshall, F.E., Boldt, E.A., Holt, S.S., Miller, R., Mushotzky, R.F., Rose, L.A., Rothschild, R.E., and Serlemitsos, P.J. 1979, Ap. J., submitted.

Marshall, F.E., Boldt, E.A., Mushotzky, R.F., Pravdo, S.H., Rothschild, R.E., Serlemitsos, P.J. 1979, Ap. J. Supplement, in press.

Mushotzky, R.F., Serlemitsos, P.J., Becker, R.H., Boldt, E.A., and Holt, S.S. 1978, Ap. J. 220, 790.

Mushotzky, R.F., Holt, S.S., and Serlemitsos, P.J. 1978, Ap. J. (Letters) 225, L115.

Mushotzky, R.F., Boldt, E.A., Holt, S.S., Pravdo, S.H., Serlemitsos, P.J. and Swank, J.H. 1978c, Ap. J. (Letters) 226, L67.

Mushotzky, R.F. 1977, Nature 265, 225.

Rieke, G.H. 1978, Ap. J. 226, 550.

Rothschild, R.E., Baity, W.A., Mushotzky, R.F., Wheaton, W.A. and Peterson, L.E. 1978, Innsbruck I.A.U. Symposium.

Rothschild, R.E. et al. 1979, Space Science Instr., in press.

Schwartz, D. 1978, Innsbruck IAU Symposium.

Shields, G. and Mushotzky, R.F. 1979, Astronomy & Astrophysics, in press.

Stark, J.P., Bell Burnell, J. and Culhane, J.L. 1978, M.N.R.A.S. 182, 23p.

Tananbaum, H., Peters, G., Forman, W., Giacconi, R. and Jones, C. 1978, Ap. J. 223, 74.

Ward, M.J., Wilson, A.S., Disney, M.J., Elvis, M., and Maccacaro, T. 1978, Astronomy & Astrophysics 59, L19.

Warwick, C.S. and Pye, J.P. 1979, MNRAS 187, 905.

Weedman, D.W. 1977, Ann. Rev. Astrons. Astrophy. 15, 69.

Weedman, D.W. 1978, M.N.R.A.S. 184, 11.

TABLE 1

LOG OF SPECTRAL OBSERVATIONS

SOURCE	X-RAY NAME	# OF OBS	TYPE	DATES (YEAR, DAY OF YEAR)
NGC3783	2A1135-373	1	point	1978,5
NGC3783	2A1135-373	2	point	1978, 190
NGC4151	2A1207+397	1	point	1977,340
NGC5548	2A1415+255	1	scan	1978,(9-15)
NGC5548	2A1415+255	2	point	1978,201
NGC6814	2A1938-105	1	scan	1978(288-295)
NGC6814	2A1938-105	2	point	1978,118
MK509	2A2040-115	1	point	1978,128
ESO141-G55	2A1914-589	1	scan	1977,(274-282)
ESO141-G55	2A1914-589	2	point	1978,101
MCG8-11-11	2A0551+466	1	scan	1978,(261-268)

TABLE 2 HEAO-1 A-2 SPECTRAL RESULTS FOR SEYFERT I GALAXIES

		POWER LAW				THERMAL		
SOURCE	OBS #	A	α	$N_x \times 10^{22}$	χ^2_ν	KT	N_x	χ^2_ν
NGC3783 (2)	1	.012	$1.74^{+.18}_{-.15}$	$2.0^{+2.0}_{-1.4}$	1.13	$33^{+\infty}_{-11}$	< 2.0	1.45
NGC3783	2	.007	$1.59^{+.22}_{-.14}$	$4.7^{+2.9}_{-2.2}$	.96	$52^{+\infty}_{-20}$	$3.2^{+1.6}_{-1.1}$	1.03
NGC4151 (4)	1	.024	$1.43 \pm .08$	$10.0^{+2.0}_{-2.0}$	1.7	> 100	$9.4^{+2.0}_{-2.0}$	1.8
NGC5548	1	.012	$1.56^{+.35}_{-.18}$	< 3.3	.84	> 20	< 3.3	.87
NGC5548	2	.014	$1.64^{+.12}_{-.12}$	$1.1^{+1.1}_{-1.0}$	1.1	42^{+13}_{-12}	$< .72$	1.38
NGC6814	1	.016	$1.75^{+.35}_{-.30}$	≤ 5.4	.7	> 12	< 5.0	.7
NGC6814	2	.019	$1.73^{+.23}_{-.22}$	$4.3^{+2.7}_{-2.0}$	.61	$26^{+\infty}_{-11}$	$2.9^{+2.9}_{-1.9}$	.6
MK509 (1)	1	.012	$1.63^{+.15}_{-.05}$	$< .65$	.91	$32^{+10}_{-9.0}$	$< .7$	.9
ES0141-655	1	.012	$1.8^{+.4}_{-.4}$	< 7	.8	$19^{+\infty}_{-6.0}$	< 2.5	.5
ES0141-655 (3)	2		(~ 3.5, ~ 1.7)			(not done)		
MCG8-11-11	1	.011	$1.66^{+.3}_{-.2}$	< 2.5	1.11	$28^{+\infty}_{-16}$	< 1.4	1.2

(1) The medium energy detector has $\Delta\chi^2 = 5$ for thermal vs. power law fits or a χ^2_ν of 1.45 for a power law and 1.60 for a thermal fit.

(2) The addition of an Fe line lowers χ^2 by 4.8, the line would have and e.w. of 440+220 eV (1σ error).

(3) Two component spectrum, approximate values for slopes shown, thermal not fit.

(4) An Fe line in the fit lowers χ^2 by 8 EW = 220$\pm$100 eV.

TABLE 3

FLUXES OF SEYFERT I GALAXIES[3]

	Integral Band Fluxes				
	2-6 keV	2-10 keV	2-60 keV	4U[1]	2A[2]
NGC3783[4]	2.3	3.9	11.8	4.5 ± .9	5.6 ± .51
NGC4151[5]	3.66	8.99	52.7	7.7 ± .86	16.3 ± 1.0
NGC5548	3.8	6.3	21.2	2.13 ± .80	4.1 ± .51
NGC6814[6]	3.3	5.5	14.3	< 15.7	3.6 ± .51
MK509	2.6	4.3	11.6	3.52 ± 3.17	4.6 ± .51
MCG8-11-11[4]	2.97	4.8	14.5	4.87 ± .50	5.1 ± .51
ESO141-655	2.4	3.8	11.6	---	2.0 ± .51

[1] 2-10 keV flux from Tananbaum et al. using 1 count = 2.4
[2] 2-10 keV flux from Elvis et al. using 1 count = 5.1
[3] Units are 10^{-11} ergs/cm^2 sec
[4] Variable higher flux shown
[5] Variable Dec data shown
[6] Possibly variable 2nd observation results shown
These fluxes are derived from the best fit models of Table 2.

TABLE 4

SOURCE INTENSITIES DERIVED FROM SCAN OBSERVATIONS

NAME	INTENSITY (Cts)	DATE	INTENSITY (Cts)	DATE
NGC3783	1.61±.18	366-370 1977	≤ .4	183.5-188 1978
NGC4151	4.44±.18	338-342 1977	7.45±.25	153-157 1978
NGC5548	2.04±.16	375-380 1977	1.94±.23	193-197 1978
NGC6814	1.47±.17	290-294 1977	1.88±.17	104-107 1978
MK509	1.45±.17	305-309 1977	1.69±.22	119-123 1978
ES0141-G55	1.19±.12	277-281 1977	1.15±.18	90.5-95 1978
MCG8-11-11	1.52±.16	263-266 1977	.57±.23	77-81 1978

1 count ∿ 3 x 10^{-11} erg/cm^2 sec in the 2-10 keV band for a $E^{-1.5}$ power law with no low energy absorption. The errors are 1σ.

FIGURE CAPTIONS

Figure 1 - 90% confidence HEAO-1 A-2 error boxes and other satellite error boxes when available.

Figure 2 - The photon spectra for 5 Seyfert galaxies from the xenon detector. All the spectra shown except that for MCG8-11-11 are from pointing data. The spectra have been unfolded from the pulse height using the best fit.

Figure 3 - The counting rate for all Seyfert I galaxies in this paper for scan 1 vs. scan 2. The dotted line indicates a constant intensity over the two observations.

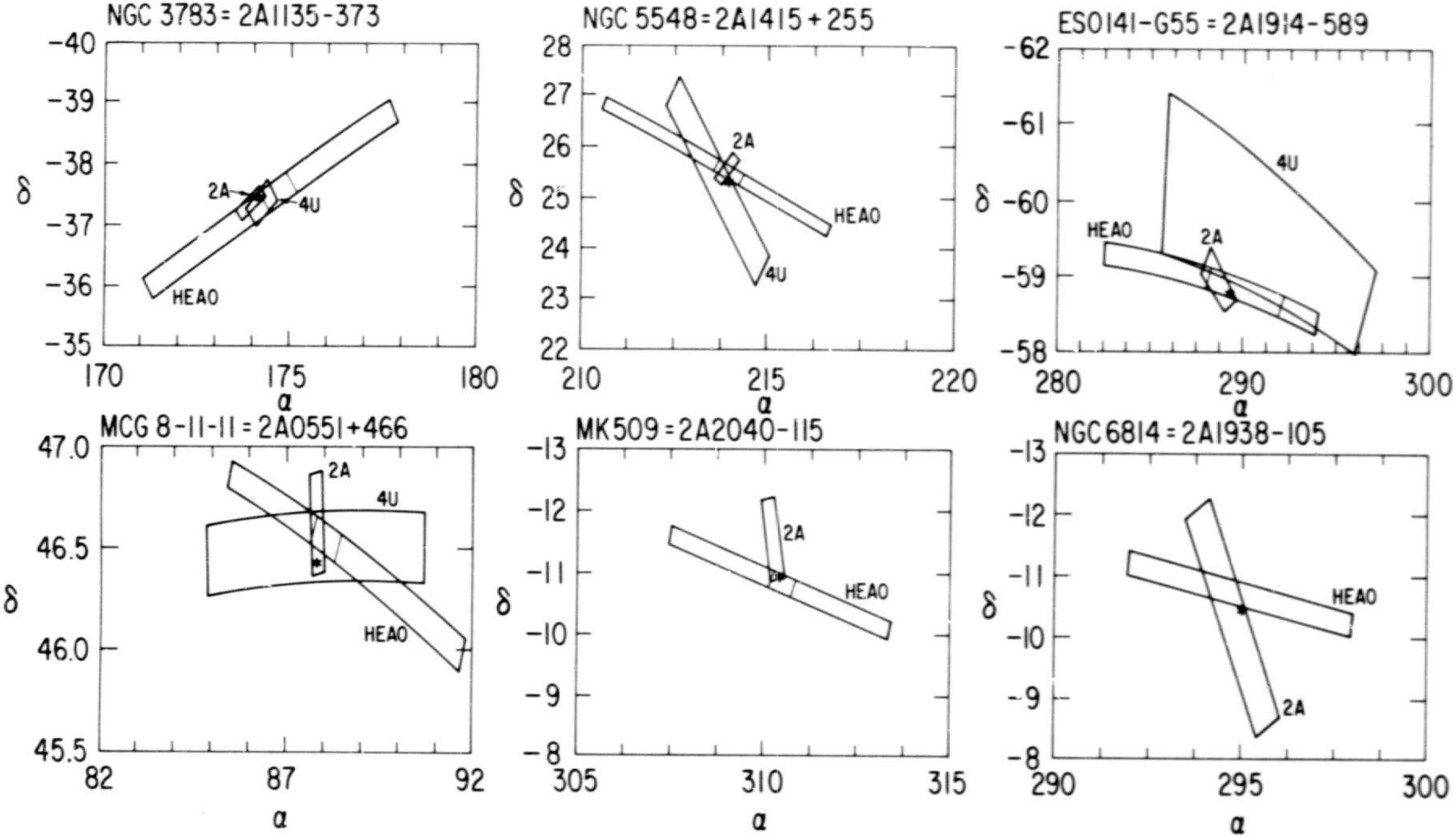
Figure 4 - The photon spectrum of ESO141-G55 for the two spectral observations.

Figure 5 - The contribution of Seyfert I galaxies to the diffuse X-ray background under the assumptions of Section V.

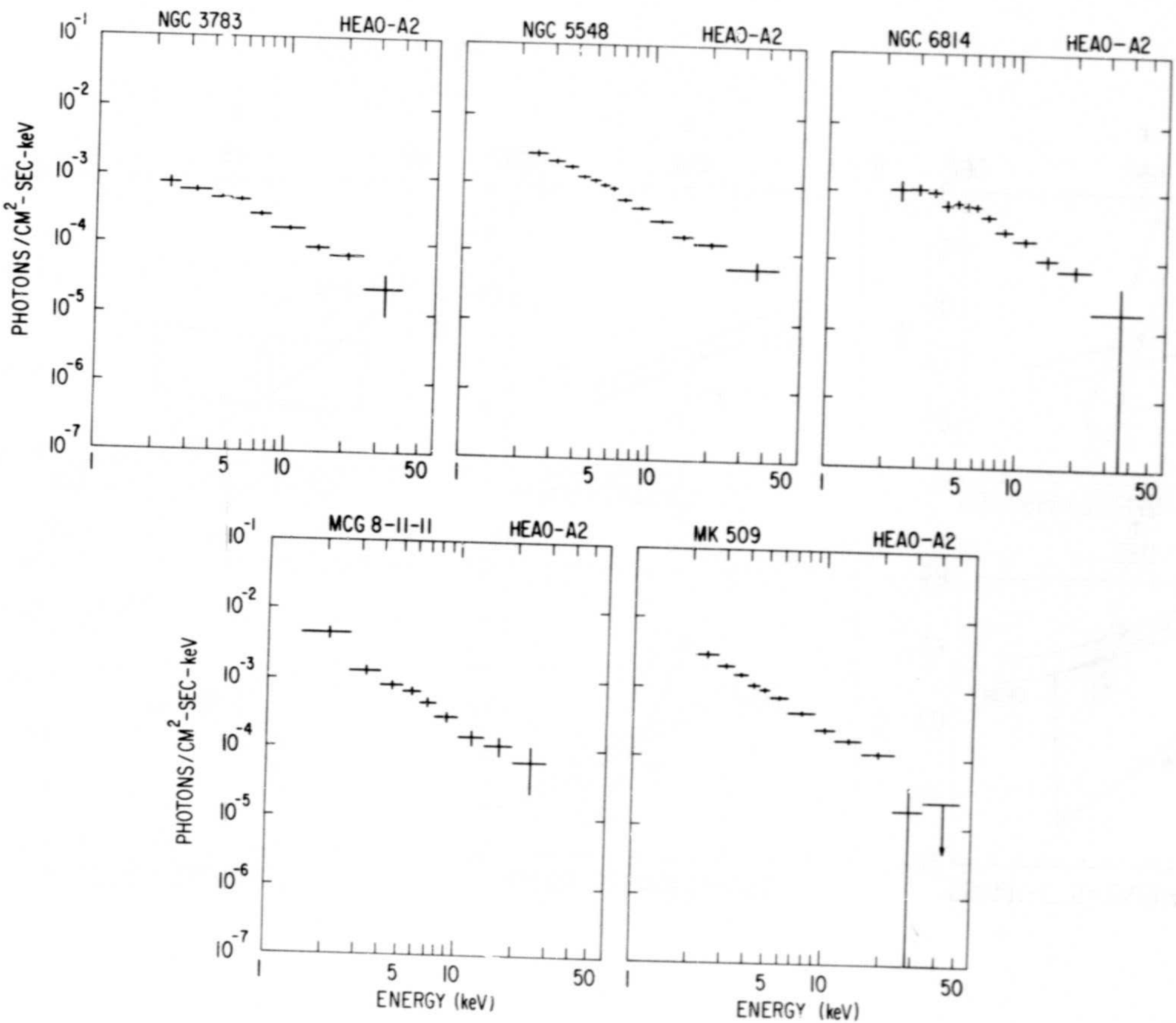
Figure 6 - X-Ray luminosity and FWZI of Hβ vs. X-ray power law index.

Figure 7 - Optical and infrared index vs. X-ray power law index, the solid points are optical power law fits, the open circles IR fits. The solid lines labeled IR or optical "fit" are the best fit linear curves. The line labeled theory is from Mushotzky 1977.

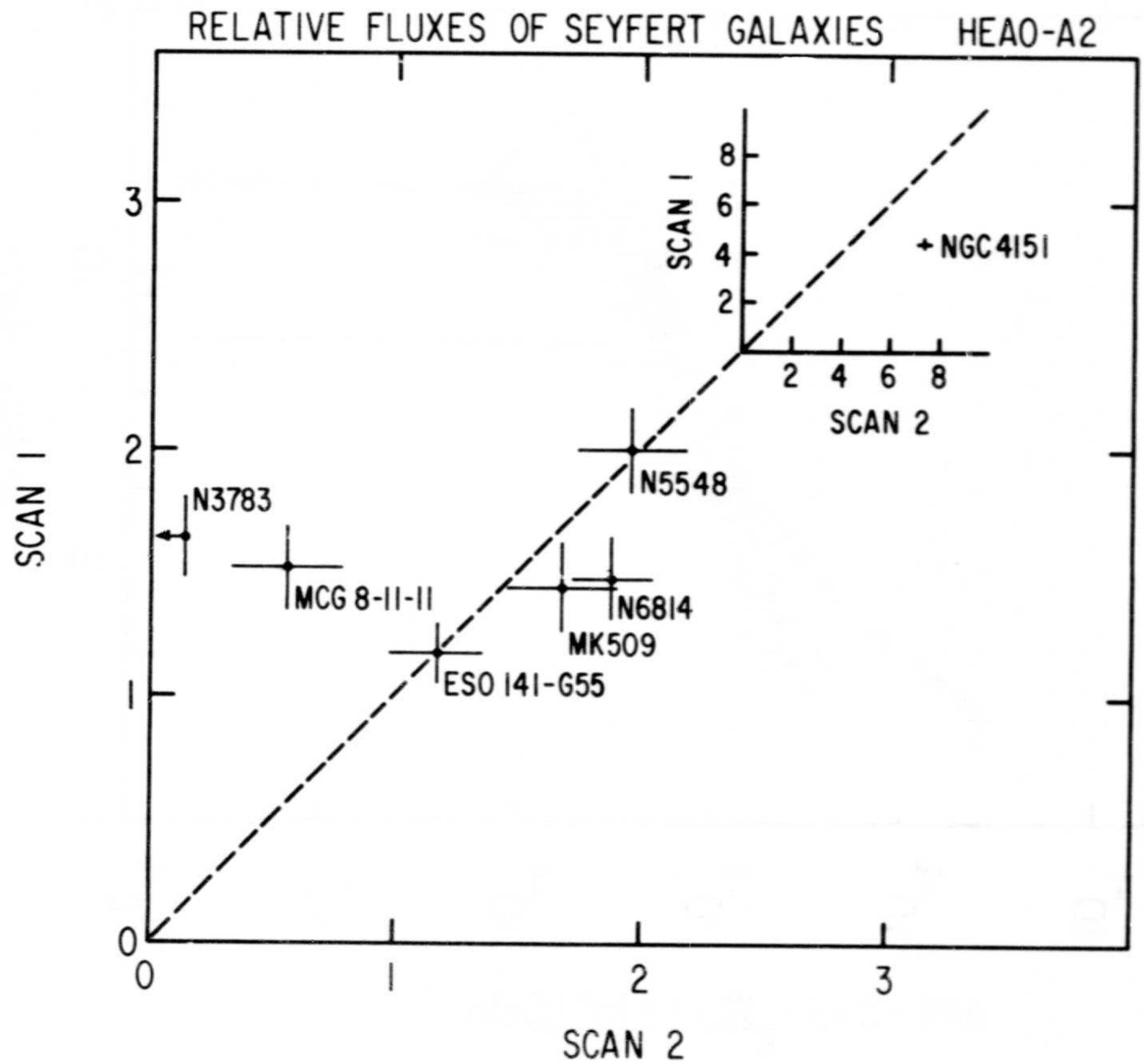
E.A. BOLDT, S.S. HOLT, F.E. MARSHALL, R.F. MUSHOTZKY and P.J. SERLEMITSOS
Code 661, Laboratory for High Energy Astrophysics, NASA/Goddard Space
Flight Center, Greenbelt, MD 20771

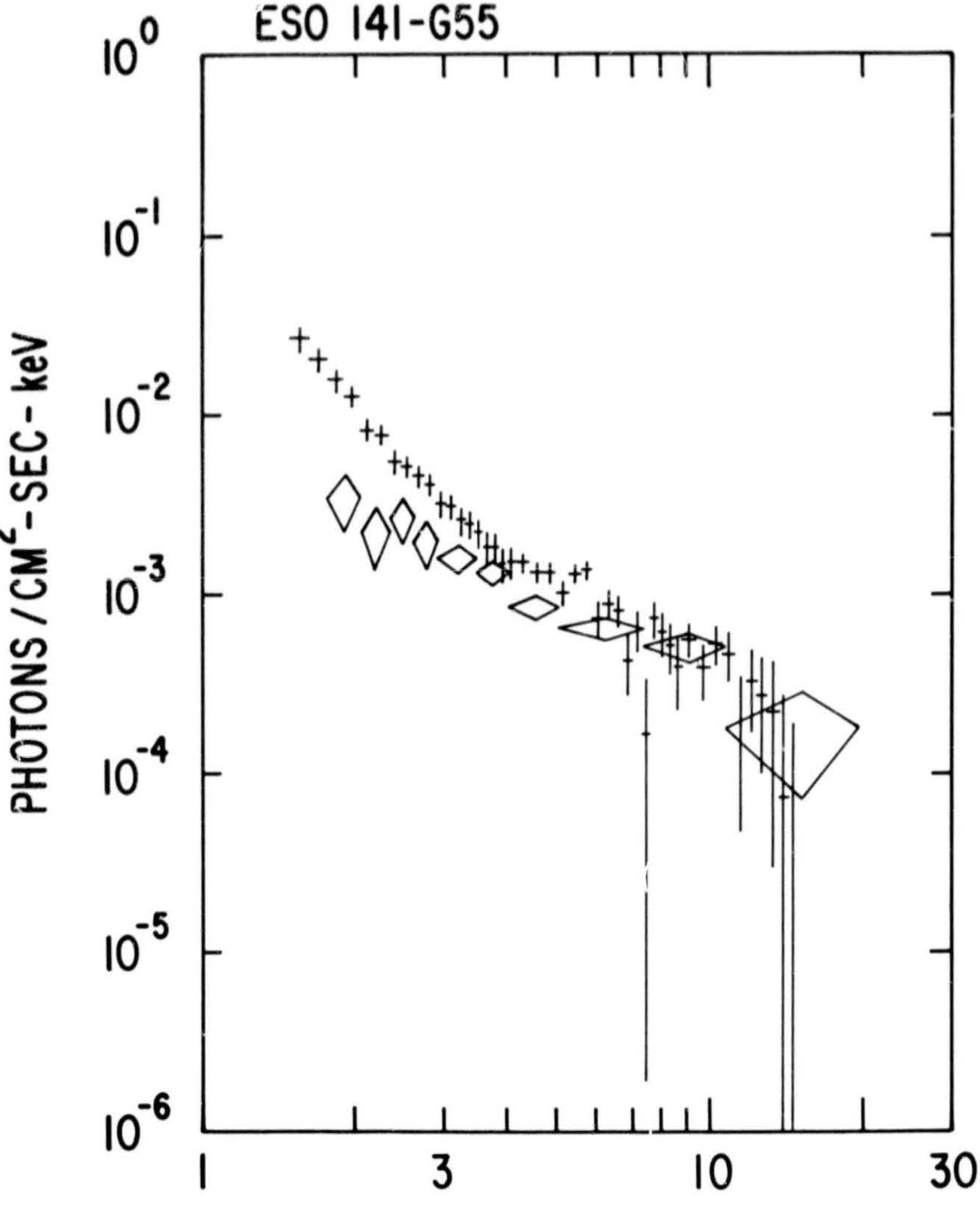


NGC 3783 = 2A1135-373
NGC 5548 = 2A1415 + 255
ESO141-G55 = 2A1914-589
MCG 8-11-11 = 2A0551+466
MK509 = 2A2040-115
NGC 6814 = 2A1938-105
HEAO
2A
4U
δ
α

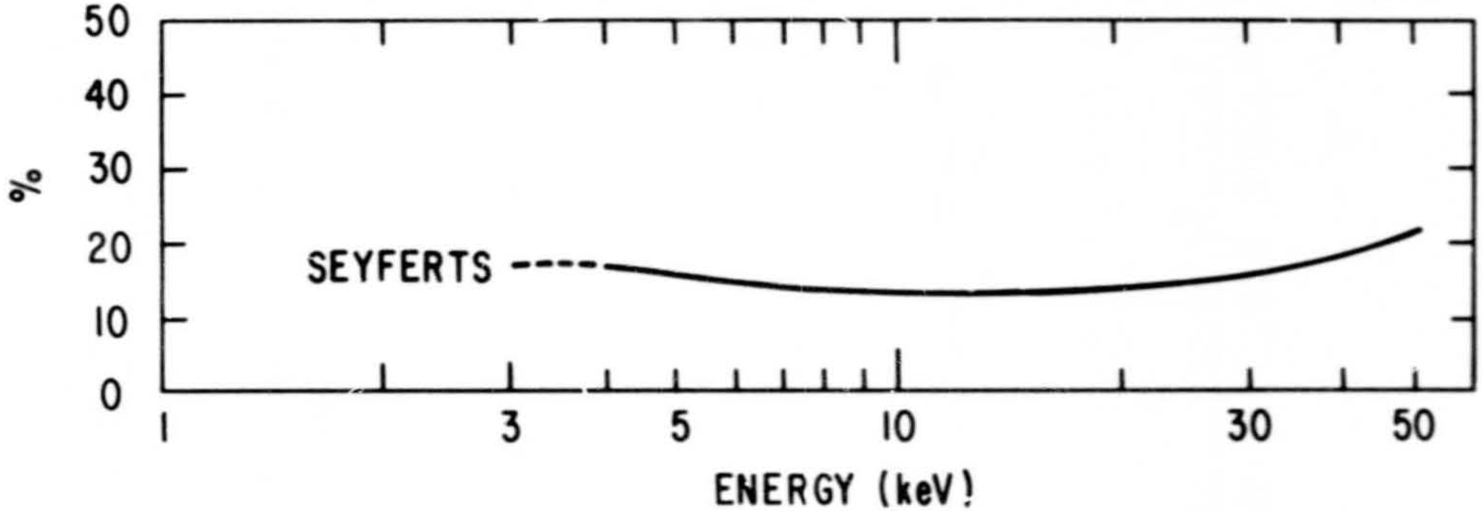


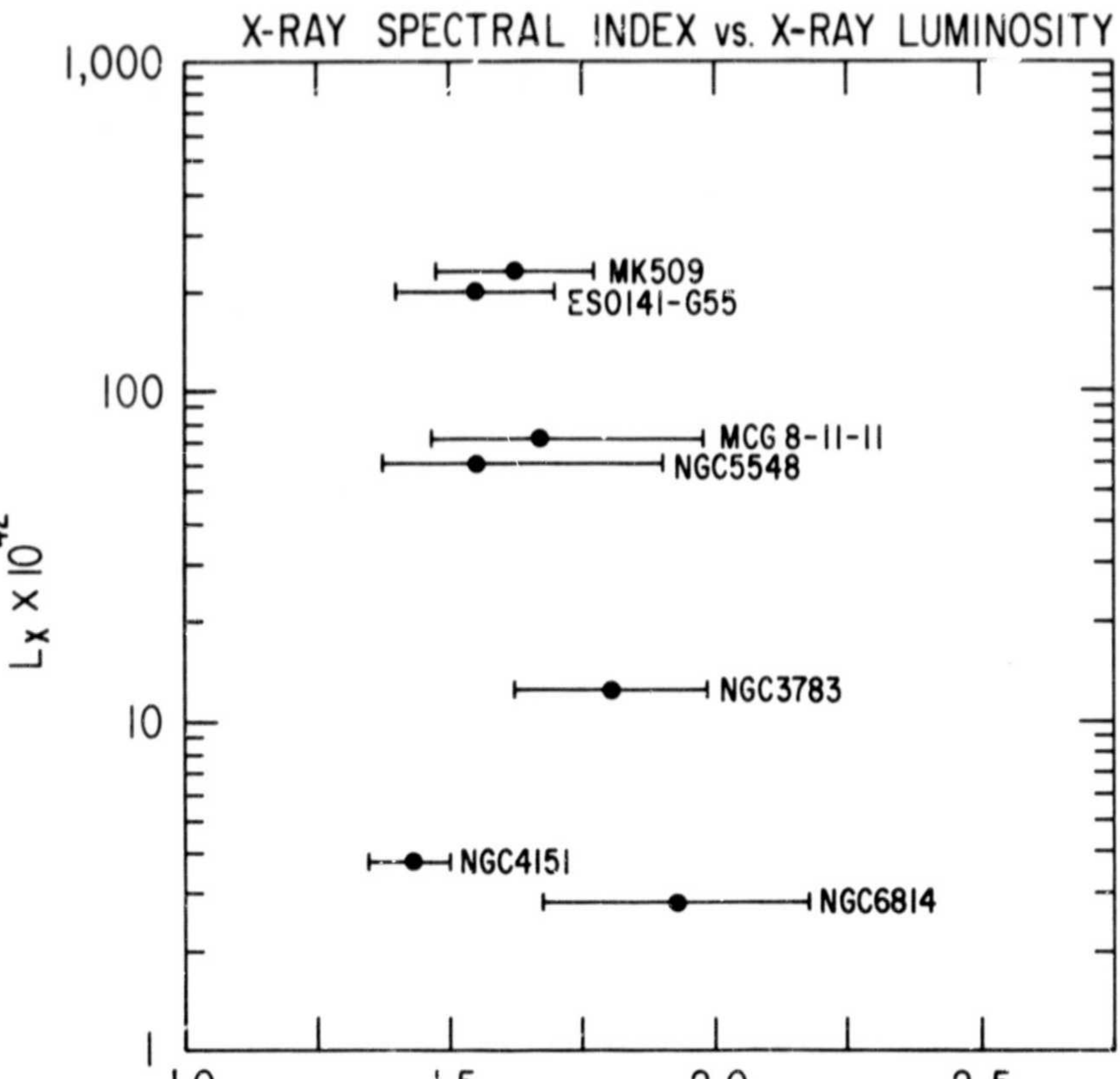
NGC 3783
HEAO-A2
NGC 5548
HEAO-A2
NGC 6814
HEAO-A2
MCG 8-11-11
HEAO-A2
MK 509
HEAO-A2
PHOTONS/CM^2-SEC-keV
ENERGY (keV)


RELATIVE FLUXES OF SEYFERT GALAXIES
HEAO-A2
SCAN 1
SCAN 2
0
1
2
3
N3783
MCG 8-11-11
ESO 141-G55
MK509
N6814
N5548
NGC4151
2
4
6
8

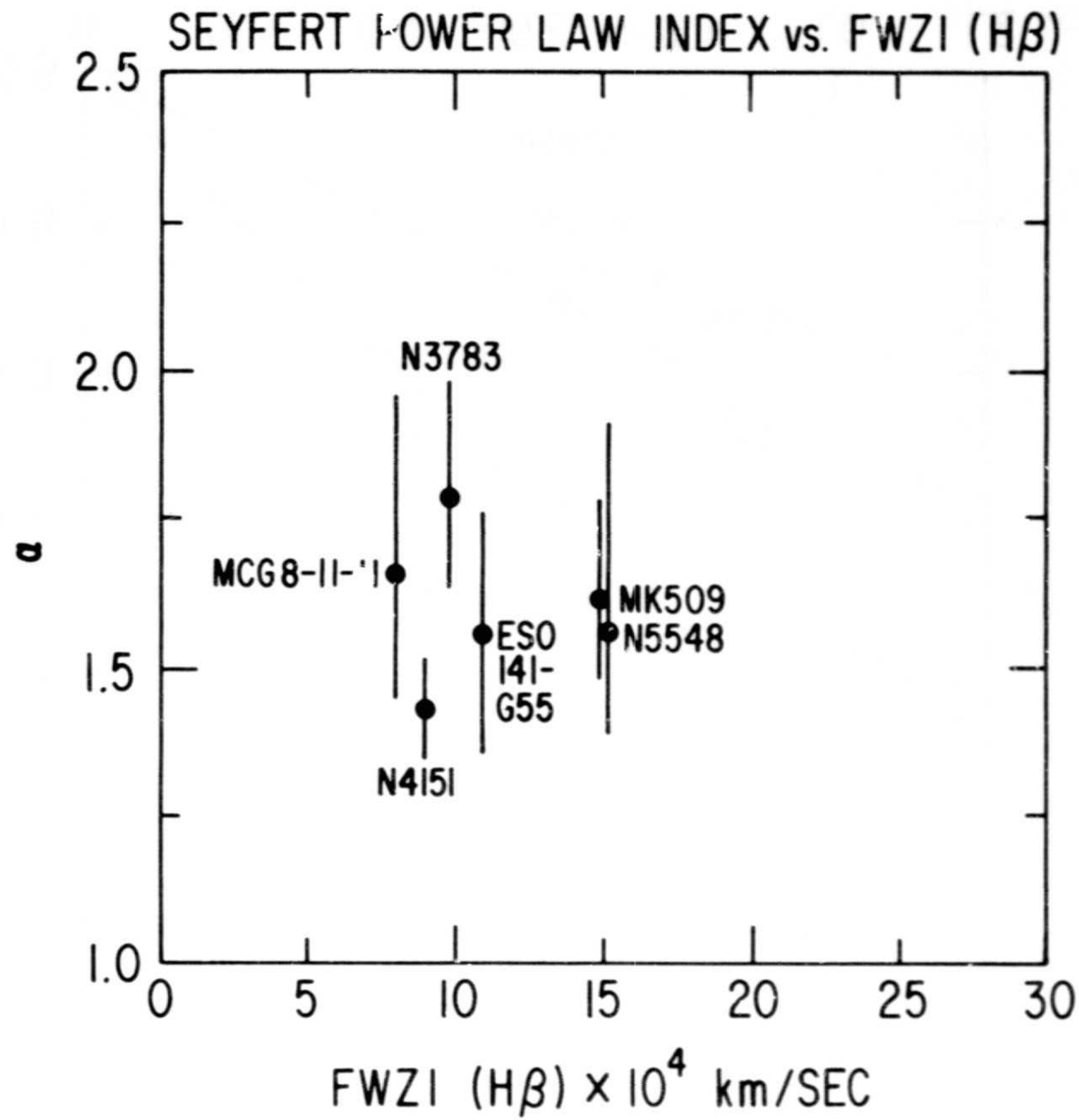

ESO 141-G55
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
PHOTONS / CM^2 - SEC - keV
1
3
10
30
ENERGY (keV)

CONTRIBUTIONS OF SEYFERT I GALAXIES TO X-RAY BKGND





X-RAY SPECTRAL INDEX vs. X-RAY LUMINOSITY
1,000
100
10
1
$L_X \times 10^{42}$
MK509
ESO141-G55
MCG 8-11-11
NGC5548
NGC3783
NGC4151
NGC6814
1.0
1.5
2.0
2.5
α


SEYFERT POWER LAW INDEX vs. FWZI (Hβ)
α
2.5
2.0
1.5
1.0
0
5
10
15
20
25
30
N3783
MCG8-11-11
N4151
ESO
141-
G55
MK509
N5548
FWZI (Hβ) x 10^4 km/SEC

X-RAY vs. OPTICAL AND IR POWER LAW INDICES